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(71) Applicant (for all designated States except US): FIBERSENSE TECHNOLOGY CORPORATION [US/US]; 755 Dedham Street, Canton, MA 02021-1402 (US).

(72) Inventor; and
(75) Inventor/Applicant (for US only): PERLMUTTER, Michael, S. [US/US]; 19 Peckham Hill Road, Sherborn, MA 01770-1605 (US).

(74) Agents: GAUDET, Daniel P. et al.; Patent Group, Foley, Hoag & Eliot LLP, One Post Office Square, Boston, MA 02109-2170 (US).

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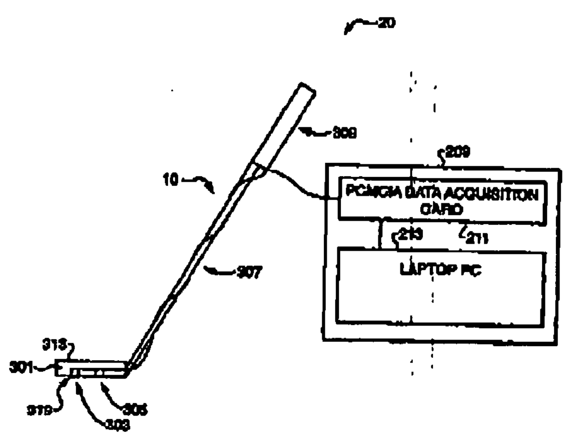

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(57) Abstract: The present disclosure is directed to systems and methods for analyzing the motion of a sporting equipment, such as a golf club, a baseball bat, a hockey stick, a football or a tennis racquet, for example. The systems comprises a motion sensing system in communications with the sporting equipment to measure motion parameters, wherein the motion sensing system has at least one accelerometer or at least one gyroscope, and a command station having a data acquisition system to process the measured motion parameters and produce data. The motion sensing system may be located on the sporting equipment or, optionally, within the sporting equipment. The systems and methods described herein can be used to determine the impact location of the sporting equipment with another object, the force of the sporting equipment, the velocity of the sporting equipment and/or angular orientation of the sporting equipment during a motion.

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METHODS AND SYSTEMS FOR ANALYZING THE MOTION OF SPORTING EQUIPMENT

Background

1. Field

This application relates to the recording and analyzing of motion. More particularly to measuring and analyzing the motion of a piece of sporting equipment.

2. Description of Related Art

Many sporting events require a participant to use a device (such as a bat, club, stick, or racquet) to propel a ball toward a particular location. One of the key facets to playing these sports well is the ability to create contact between the device and the ball in such a manner that the player can predict where the ball is likely to end up after the impact between the device and ball. In the game of golf, for example, when a golf ball is hit by a golfer, there are a large number of factors which control the resultant motion of the golf ball. Some of these, over which the golfer has control, are the velocity and direction which is imparted onto the golf ball by the club. In putting, these factors are particularly acute.

Training devices for golf swing and putting attempt to provide a golfer with the ability to practice motions they will use in a game repeatedly under controlled conditions (generally with immediate feedback on their performance). Many also try to encourage the player to use particular methods which have been previously found to be more successful (e.g. in golf the grip on the club and the placement of the feet). Some of these devices limit the swing of the player who is practicing to the "correct" swing by forcing the player's swing to occur in a dimensionally limited space. These devices have some major drawbacks, however. For instance, a player may become reliant on the resistance or force provided by the device to complete the correct swing and when the device is not present the player losses much of the benefit they may have obtained from the use of the device. These devices may also be too cumbersome and bulky to be used on a golf course limiting the player's ability to use them under conditions most similar to play. Finally, such devices are generally frowned upon by a player's competitors during actual play meaning that the player is forced to attempt to transition knowledge from the controlled training environment to the new environment of competition.

Other types of devices analyze golf swings through the use of specially designed motion sensing apparatuses. These devices are generally external to the club for measuring the club's motion in simulated swings. These devices also have certain disadvantages. External systems are often limited by their processing speed. Many, which use video, are limited by the frame rate of the recorder and are unable to record precise motion of the club at the point of impact because of the club's speed. Further, these type of systems are usually limited in measurement dimensions because detectors have to avoid being hit by the club during the swing. Finally, these systems are not easily transportable and often require specific setup making them impractical or impossible to use on the golf course.

A further problem with training devices is that they can only measure swings and motion and tell a player whether he is within parameters of a mathematically "good" swing. These parameters may be set from calculation, theory, or possibility of success but cannot be determined from actual competitive play to take into account factors which master golfers take into account, or compensate for, unconsciously. In sports, there are many champions and many of the champions have their own unique nuances to their style of play. These champions may have facets of their play that one would like to be able to achieve beyond the perfection of the basic skills of ball control. None of the above systems enable a user to compare their play with another particular golfer playing at a particular time (e.g., to compare their putting with the 20 foot putt that previously won a Masters Tournament). To measure the player during actual play, it is necessary to use unobtrusive methods that do not interfere with the play of the game and most practice devices do not allow such use.

In a training device, it may also be desirable to not train a golfer in controlling their body motion as is currently done, but to simply train the golfer to obtain a motion in a particular part of the club by whatever means necessary. Currently, training devices try to coordinate the body motion of a golfer, which can be very difficult as golfers come in many shapes and sizes. Many existing systems have this limitation because since there may not be data available about the motion of the actual club. At the same time, while it may be impossible for a 6'6" tall golfer to identically copy the full motion of a 5'2" tall golfer, with a completely different motion, he may be able to exactly copy the motion of a club head used by that golfer with a completely different motion.

The systems discussed above illustrate the shortfalls of existing sport trainers.

Summary

For all these reasons and previously unidentified problems in the art, it is desirable to have systems for analyzing the motion of a sporting equipment (i.e., a sport training system) where the system can be incorporated into the sporting equipment (e.g., golf club, golf attire, baseball bat, hockey stick, football, tennis racquet etc.) or other in such a way that the equipment can be used for both practice and competitive situations, and thus can be used on an actual playing surface under actual playing conditions.

It is further desirable to have a sport training system that can enable measuring, recording and analyzing a the motion of a sporting equipment during actual competitive play and one can also use that analyzed the motion of the equipment to heap train another player to replicate a desirable motion. In golf for example, the recording of the golf swing motion can be used to analyze and compare the motion of the club of successful puts (or drives) and compare these to club motions of bad puts (or drives). Golf club motions (i.e., swing, stroke) can also be analyzed over a period of time to identify what features of a player's stroke might have changed.

The present disclosure is directed to systems for measuring motion of a sporting equipment, the system comprising a motion sensing system in communications with the sporting equipment to measure motion parameters, the motion sensing system having at least one accelerometer or at least one gyroscope. In different embodiments, the sporting equipment can be a golf club, a baseball bat, a hockey stick, a football or a tennis racquet and the like. In some embodiments, the motion sensing system can be located on the sporting equipment, or alternatively, within the sporting equipment.

In accordance with one aspect of the present disclosure, the accelerometers and gyroscopes can be micromachine devices.

In accordance with another aspect of the present disclosure, the systems may further include a command station having a data acquisition system to process themeasured motion parameters and produce data and, optionally, a display monitor. In some embodiments, the data acquisition system may processes the measured motion parameters and produce data

representative of an impact location of the sporting equipment, the a velocity of the sporting equipment, or an angular orientation of the sporting equipment.

In accordance with a further aspect of the present disclosure, the motion sensing system can include memory for storing the measured motion parameters. In some embodiments, the memory may be detachable from the sporting equipment.

In accordance with yet a further aspect of the present disclosure, the systems described herein can include a transmitter to transmit the measured motion parameters to a command station. In some embodiments, the transmitter may be a wireless communications transmitter such as a radio-frequency transmitter or an Infrared-frequency transmitter, for example. Additionally, in some embodiments, the wireless communications transmitter can be capable of transmitting the measured motion parameters in accordance with the Bluetooth or IEEE 804.12. wireless communication protocols.

In accordance with an additional aspect of the present disclosure, the data acquisition system can include a data error correction module to compensate for an error rate of the motion sensing system.

The present disclosure is also directed to a golf club comprising a club head, a shaft and a motion sensing system to measure motion parameters of the golf club during a golf swing, the motion sensing system having at least one accelerometer or gyroscope. In some embodiments, the motion sensing system can be located on the golf club, or alternatively, within the golf club.

The present disclosure is also further directed to methods of analyzing a golf swing, where the methods include having a motion sensing system in communications with a golf club to measure golf swing motion parameters, wherein the motion sensing system has at least one accelerometer or gyroscope, and processing the measured motion parameters to produce data. In some embodiments, the methods may also include displaying the produced data on a display monitor.

In accordance with an aspect of the present disclosure, the produced data can be representative of an impact location of a golf ball on a club face of the golf club.

In accordance with another aspect of the present disclosure, the produced data can be representative of a velocity of a club head of the golf club.

In accordance with a further aspect of the present disclosure, the produced data can be representative of an angular orientation of a club face of the golf club. In some embodiments, the data acquisition system can provide an angular orientation of the club face when the club face impacts a golf ball. In other embodiments, the data acquisition system can provide a reference angular orientation of the club face at an initiation of the golf swing.

Further features and advantages of the present disclosure will become apparent from the following descriptions of the detailed embodiments and from the claims.

Brief Description Of Drawings

FIG. 1 shows an embodiment of a golf putter with an external motion sensing system;

FIG. 2 shows an embodiment of a block format layout of a motion sensing system and command station;

FIG. 3 shows an embodiment of a golf club and a command station;

FIG. 4 shows another embodiment of a golf club and a command station;

FIG. 5 shows another embodiment of a block format layout of a motion sensing system and command station; and

FIG. 6 shows a display for displaying the data of the command station.

Detailed Description of the Preferred Embodiment(s)

While the following embodiments and descriptions are generally discussed regarding systems and methods for measuring the motion of a golf club during a golf swing, persons skilled in the art will appreciate how the systems and methods discussed herein can be applied to other pieces of sporting equipment such as baseball bats, a hockey sticks, footballs, tennis racquets, and the like.

The term "actual conditions" relates to play on a golf course or similar environment. For instance, it could be useful to use the systems and methods discussed herein on a driving range as the driving range itself is designed to simulate the actual conditions of golf play (e.g. a golf ball is hit off a tee with a club that would be used in regular play). Therefore one should think of actual conditions being those where equipment that would be

used competitively by a golfer would normally be used, whether the play is as part of a game or only "practice." Further, actual conditions would not require the golfer to go through a special series of steps which could detract from the play of a golf game (e.g., the golfer would not need to set up a series of sensors around a ball before taking a shot). In an embodiment, the systems and methods described herein are designed so that a user can play golf on a course with their equipment and can have information about their swing and their play relayed to a command station for use anytime during or after the game. In addition, in an embodiment, the golf club appears similarly to those that do not determine the motion of the golf swings; furthermore, in some embodiments, the golf club can be used in professional, regulation play.

It would be understood by one of skill in the art, however, that the principles and devices discussed herein could be incorporated without undue experimentation into a wide variety of sporting equipment.

As a golfer, it is desirable to know when one is hitting a ball in a manner different than is intended. In particular, if there is a systematic problem (i.e. the ball is always hit toward the toe end of the face) a golf instructor, or the player, may be able to understand and correct an aspect of play to correct for the problem. For instance, the golfer may move his feet back or play with a longer putter to eliminate the problem and therefore improve their game. Provided below are embodiments of a golf club containing a motion sensing system allowing a golfer to receive feedback regarding the motion of a golf club. These embodiments can then be used to provide indications of problems in a golfer's play which the golfer can attempt to correct by increased practice, altered movement, different equipment, or other things.

There are several factors relevant to a golf swing which can affect how well a golf ball will travel. One factor has to do with where on the club face the ball is hit. It is generally desirable for the golfer to hit the ball as close to the centerline of the club face as possible because, when hit at this point, the club face generally will not experience any angular rotation upon impacting with the ball. Thus, if the angular rotation of the club face can be minimized at the point of impact, the ball should travel in a straighter line. In contrast, when a golfer strikes the golf ball near the toe or the heel (defined below) of the club face, the club face will slightly rotate when the mass of the ball comes into contact

with the club face. This interaction (i.e., the rotation) can not be controlled by the golfer and can lead to the ball traveling in a direction which was not intended by the golfer. In certain embodiments of the systems and methods described herein, therefore, it is desirable to be able to determine where on the club face the ball is hit so that the golfer can adjust their play style (or equipment) as needed, e.g., move the hitting point closer to the centerline.

A second factor that can affect the travel of the golf ball is the amount of force that is imparted onto the ball by the golf club. The force of the golf club impacting the ball is dependent upon the velocity of the golf club (i.e., the club face) as it hits the ball and the weight and balance of the golf club. The motion of the golf club and in particular, the motion of the club face, greatly determines how far the ball will travel. For example, too little force can cause the ball to fall short and teetering on the edge of the cup, while too much force can cause the ball to overshoot the cup. In certain embodiments of the systems and methods described herein, therefore, it is desirable to be able to measure the velocity of the golf club as it travels through a swing, and it is particularly desirable to be able to determine the velocity of the club face at the time of impact.

Yet another factor that can affect the travel of the golf ball is the plane of the club face as it strikes the golf ball. If the golfers swing is not straight, the club face may strike the ball at an angle (relative to the ball and/or playing surface) which can cause a force to be applied to the ball in an unintended direction. This can result in the ball deviating from its desired course or to have an undesired spin. In certain embodiments of the systems and methods described herein, therefore, it is desirable to be able to determine the angular orientation of the club face.

FIG. 1 depicts a golf club 10 that can be used in analyzing a golf swing. While the golf club 10 depicted in FIG. 1 is a putter-type golf club (i.e., a putter), the disclosure herein is equally applicable to any type golf club, e.g., driver, sand wedges, irons, etc. Golf club 10 has a putter golf head 113, a shaft 115 and a handle (not shown). The golf head 113 has a club face 101 and a centerline 107. The ends of the club face 101 are referred to as the heel 103 and the toe 105, where the heel 103 is the end of the club face 101 closest to the golfer and the toes 105 is the end furthest from the golfer. The centerline 107 is on the top

of the golf head 113 and indicates the location of the center of gravity along the y-axis (cg_y) of the golf club 10. If the club face 101 impacts a golf ball (not shown) at a point corresponding to the centerline 107 (i.e., at the cg_y), then the club face 101 generally should not experience an angular moment about the z-axis (i.e., the club face 101 should not rotate at impact). An unexpected rotation of the club face 101 can cause the golf ball to travel in a direction (or in a way) which may not have been intended. Thus, centerline 107 assists the golfer in identifying where on the club face 101 the golfer may desire to hit the ball. Reference lines 109 and 111 are present on the top of the golf head 113 to further assist the golfer in identifying where on the club face 101 the golfer may desire to hit the ball.

When the golfer makes a putt with the golf club 10, the club head 113 may be swung so that the club head 113 moves in a gentle arc which is tangential to plane of play 117 (i.e., the x-y plane of the ground) and approximately parallel to the line of the centerline 107. A golfer's exact skill would determine the exact nature of the motion, as would the golfer's intended hitting power, placement of the ball and other factors. The golf ball, when struck by the club face 101, should travel away from the club face 101 in a path generally perpendicular to the club face 101 if the ball is hit properly and unaffected by any external influences.

FIG. 1 further depicts the golf club 10 having a motion sensing system 119 in communications with the club head 113 to measure a motion parameter of a golf swing. Golf swing motion parameters can be any suitable metrics that can be used to define the physical attributes of a golf swing. Thus, golf swing motion parameters may include the club head 113 linear and angular accelerations in and about the x, y, and z axes, for example. FIG. 1 depicts the motion sensing system 119 being attached to a portion of the top of (i.e., "on") the club head 113 (and behind the club face 101).

As stated, the motion sensing system 119 can detect, i.e., measure, motion parameters of a golf swing. In the embodiment shown in FIG. 1, the motion sensing system 119 is mounted on the club head 113 since the club head's 113 motion directly effects the motion of the ball after the club head 113 strikes the ball. In other embodiments, the motion sensing system 119 may be located within (i.e., internal) the club head 113. In some of these embodiments, the club head 113 may have an outward appearance which is identical to a club head which does not contain a motion sensing system 119. In yet other

embodiments, the motion sensing system 119 may be located on the shaft 115, or alternatively, within the shaft 115.

In some embodiments, the motion sensing system 119 be designed so as to be removable and replaceable from the golf club 10. In this way, the motion sensing system 119 can be a modular add-on device which can be installed on a conventional golf club so as to analyze a golf swing using that golf club and then the motion sensing system 119 can be removed and reinstalled on a different golf club.

In other embodiments, the motion of a different part of the golf club 10, or even a different part of the golf equipment (such as the ball) may wish to be analyzed and thus the motion sensing system 119 may be attached in proximity to this different location. In a yet further embodiment, a motion of a particular part of the golfer's body may be desired and the motion sensing system 119 could therefore be placed in proximity to that portion of the golfer's body.

Depending upon which motion parameters one wishes to measure, the motion sensing system 119 can include an accelerometer, a gyroscope, and/or combinations of accelerometers and gyroscopes. To measure a linear acceleration along a single axis (relative to the golf club 10 or club head 113), for example the x-axis, a single accelerometer properly oriented to that axis could suffice. To measure linear accelerations in additional axes, additional accelerometers may be required. Similarly, to measure an angular acceleration about a single axis (e.g., the z-axis), a properly oriented single gyroscope could suffice; additional gyroscopes may be required to measure angular accelerations in other axes.

In some embodiments, the accelerometer(s) and/or gyroscope(s) may be fabricated micromachines, or an array of fabricated micromachines. A micromachine, as that term is used herein, may be a polisilicon structure built on a silicon wafer or any other structure that would qualify as a micromachine. Persons skilled in the art will appreciate the wide variety of micromachine accelerometers and gyroscopes that are suitable and readily available. For example, the accelerometers and gyroscopes disclosed in U.S. Patents Nos. 6,167,757 and 6,067,858, respectively, the entire contents of which are herein incorporated by reference. In addition, micromachines, as described herein, may be micro electro-mechanical sensors

(MEMS). These include devices manufactured by Analog Devices Inc. among others. These micromachines may produce analog, digital, or any other form of output.

In other embodiments, micromachines need not be used, and instead other sensors (e.g., accelerometers and gyroscopes) such as, but not limited to, automotive-grade accelerometers and gyroscopes, fiber optic gyroscopes, vibrating quartz gyroscopes, or similar devices which will be readily understood by those persons skilled in the art may be used.

FIG. 2 illustrates in block format one embodiment of a system 20 for analyzing the motion of a sporting equipment. System 20 includes a motion sensing system 119 and a command station 209. The motion sensing system 119 of FIG. 2 has a gyroscope 203 and an accelerometer 205. The motion sensing system 119 is in communications with, e.g., is coupled to, a piece of sporting equipment (not shown in this figure). The command station 209, which is generally external to the piece of sporting equipment, includes a data acquisition system 211 and a personal computer 213 having a display monitor 215. The gyroscope 203 and accelerometer 205 of the motion sensing system 119 are in communications with the data acquisition system 211 of the command station 209. The gyroscope 203 and accelerometer 205 detect (i.e., measure) an angular acceleration and a linear acceleration, respectively, exerted on a piece of sporting equipment. The measured motion parameters (e.g., the acceleration data) can be transmitted to the data acquisition system 211 of the command station 209 via appropriate physical wire paths (e.g., wires or cables) or wireless paths, as further discussed below. The data acquisition system 211 can be capable of processing the measured motion parameters from the motion sensing system 119 to produce data indicative of the golf swing. The data can take many different kinds of form, all indicative of motion, including, for example, a two-dimensional or three-dimensional representation of the golf swing, the velocity of the club head as a function of time, the velocity of the golf head at a point of impact, the angular orientation of the club head as a function of time, etc. Suitable data acquisition system's 211 include commercially available 12 channel PCMCIA data acquisition cards (where the measured motion parameters from each sensor is "channelized"), amongst others. Persons skilled in the art will appreciate the wide variety of data acquisition systems which may be used. The

command station 209 which may be, but is not limited to, a computer or other processing device, may then process the data produced by the data acquisition system 211 to provide a textual and/or graphical display of the produced data via the display monitor 215.

In some embodiments, the command station 209 may further include a data error correction module (not shown) to compensate for the error rates (e.g., calibration and in-run drift error rates) which may be inherent in the accelerometers 205 and/or gyroscopes 203 used in the system 20. The use of a data error correction module therefore may allow the command station 209 to produce more accurate data. The data error correction module, which could be a hardware or a software embodiment, can operate based upon some general assumptions regarding a typical golf swing (e.g., a drive or a put, etc.) like, for example, the typical time duration of a put. If for example, a typical put has a duration of 1.5 seconds and the gyroscopes 203 used have a drift rate of 4°/sec, then the data error correction module could properly compensate for the gyroscopes 203's statistical drift error that would be expected over this golf swing duration. In addition to a golf swing duration metric, the data error correction module could also provided correction feedback to the command station 209 based upon assumptions regarding the nature of a typical golf swing (e.g., the path that is typically carved out) and/or the typical position of the start of a golf swing. The data error correction module can be a component of the data acquisition system 211, the computer 213 or be separate stand-alone component within the command station 209. Persons skilled in the art will appreciate how the data error correction module can be used in conjunction with the measured motion parameters so as to produce more accurate data. Also, the use of a data error correction module may permit the use of less expensive (e.g., automotive grade) accelerometers 205 and gyroscopes 203 that typically have higher error rates than the more expensive models.

In some embodiments, the measurement of the motion parameters can be performed through the use of sensors which are small enough to be used in proximity to certain key points of sporting equipment, such as the club head, without undue (or in one embodiment any) performance degradation. In addition, devices are desirable that can survive the rigors of the club impacting the ball. Such sporting equipment may then be used by both the professional and the amateur in any way that would regularly use golf equipment that does not include sensors or a motion sensing system. Therefore the golfer could use this club as

their regular club and the equipment could be used under actual conditions. This would also allow a golfer to play golf in their normal game setting and yet be able to obtain training information from their game. In an embodiment, the equipment could replace both the players training devices and their play devices, allowing training to occur at all times, including during competitive play.

FIG. 3 illustrates an embodiment of a system 20 for analyzing the motion of a sporting equipment, and in particular, as shown in FIG. 3, a golf club 10 having a club head 313, a shaft 307, a handle 309 and a motion sensing system 319. FIG. 1 illustrated one manner of locating the motion sensing system 119 on the club head 113 of the golf club 10 - a motion sensing system 119 attached externally and unobtrusively to the golf club 10 in a manner that does not interfere with the golf club's 10 playability. FIG. 3 shows another embodiment of a golf club 10 having a motion sensing system 319 to measure motion parameters of the golf club 10 during a golf swing. The motion sensing system 319 has at least one gyroscope 303 and at least one accelerometer 305 forming a micromachine array that can be located within the club head 313. The club 10 can appear externally similar to a conventional golf club and can be used to strike golf balls in practice or competitive play. In particular, the gyroscope 303 and accelerometer 305 sensors may be located within the club head 313 so as to not be externally visible. In alternative embodiments, the golf club 10 can be any golf club that has been altered after manufacture to contain the systems discussed herein.

In FIG. 3 the micromachine array may be comprised of three independent "packages" of micromachines. Each of these packages can be a ceramic dual inline package as is known to the art. In such a package there is included two accelerometers and two gyroscopes. The gyroscopes and accelerometers are placed in two-dimensions (e.g., relative to the club head 313) so that the package's motion (both in terms of displacement and acceleration) can be measured in two dimensions. Ideally, each package is small enough to be placed inconspicuously inside the golf club 10 or golf club head 313. Such packages may be around 0.39" x 0.42" x 0.22", for example. A package having these dimensions is available commercially from Analog Devices, Inc. The packages may be smaller however. For instance another package with similar micromachine components is also available from

Analog Devices which is only 0.2" x 0.2" x 0.1". A wide variety of suitable packages may be used.

The measured motion parameters of the motion sensing system 319 can be provided to a command station 209 having a data acquisition system 211 which can process the measured motion parameters to produce data which is representative of the motion of a golf swing. The command station 209 may be located with the golf club 10 (e.g., installed on the golf club 10) or may be remotely located at a distance from the golf club 10. The measured motion parameters of the motion sensing system 319 may be analog or digital signals; the analog or digital signals can be changed from either format to the other, or a different format, at any time via analog to digital (A/D) or digital to analog (D/A) converters, as is know to those of skill in the art. In the embodiment illustrated in FIG. 3, the measured motion parameters of the motion sensing system 319 can be transmitted via wires as shown to the external data acquisition system 211 of the command station 209.

The use of accelerometers and gyroscope have certain particular advantages. In action, each of the gyroscopes can be used to measure the change of direction or angle of the club head, while the accelerometers can measure changes in the speed of the club head. A total of three packages (as described above) may be arranged so as to provide two measurements in each of the three orthogonal dimensions relative to the club head 313 (i.e., the x, y, and z axes of the club head 313). The use of three packages can allow the motions in each dimension to be double-checked, since there are two readings in each dimension, and/or can allow for displacement between the packages to show certain types of motion. For instance, placing one package at the heel 103 and one at the toe 105 (of FIG. 1, for example) of the golf club 10 may permit the detection of rotation of the club head 113 about a point between these two sensor arrays. This may be useful to insure accurate data for the motion of the club head. One of skill in the art, however, would see that any number of packages or any combination of sensors including any number of gyroscopes and or accelerometers can be used depending on the type of information required and the level of measurement redundancy desired.

For example, accelerometers 305 of the motion sensing system 319 can be used to measure the linear acceleration(s) exerted upon the club head 313 during a golf swing. The

linear acceleration can be measured in either one, two or three dimensions relative to the club head 313 - depending upon the number and type of accelerometers 305 used and the orientation of the accelerometers 305. The data acquisition system 211 of the command station 209 can then process these measured linear acceleration motion parameters to produce data which is representative of the velocity of the club head 313 (in either one, two or three dimensions), and/or produce data which is representative of the distances traveled by the club head 313 (again, in either one, two or three dimensions).

Gyroscopes 303 of the motion sensing system 319 can be used to measure the angular acceleration(s) of the club face 301 both before, during, and after impact with a ball. The angular acceleration can be measured in either one, two or three dimensions - depending upon the number and type of gyroscopes 303 used and the orientation of the gyroscopes 303. The data acquisition system 211 of the command station 209 can then process this measured angular acceleration motion parameters to produce data which is representative of the angular orientation of the club face 301 both before, during, and after impact with a ball.

In some embodiments, the angular orientation of the club face 301 at the point of impact may be determined relative the what the angular orientation of the club face 301 was upon the initiation of the golf swing. This can be advantageous since the orientation of the club face 301 at the initiation of the golf swing is the orientation of the club face 301 at which the golf intends to impact the ball. In such embodiments, the initiation of the golf swing may be determined by measuring and detecting some threshold amount of motion, such as an acceleration via accelerometers 305, which may be indicative of an initiation of a golf swing. Alternatively, the initiation of the golf swing may also be established by determining the time and spatial relation at the point of impact and then extrapolating the measured motion parameters backwards in time (and space) to determine the initiation of the swing (and the angular orientation of the club face 301 at this point). In yet other embodiments, the initiation of the golf swing may be determined by measuring and detecting some threshold period of motion inactivity. Prior to initiating a golf swing, many if not most golfers will place the club face 301 immediately adjacent to the golf ball and pause for some period as they prepare for their golf swing. This period of inactivity, which can be measured by an accelerometer 305, for example, thus may be indicative of the period

immediately preceding the initiation of the golf swing and thus the initiation of the golf swing may be determined in this way.

By utilizing a motion sensing system 319 which has, at a minimum, a gyroscope 303 that can measure the angular acceleration about the z-axis of the club head 313 and an accelerometer 305 that can measure the linear acceleration in the club head's 313 x-axis, the impact location (of the golf ball) along the club face 301's y-axis can be determined. An impact with a ball at a point away from the centerline 107 of the club face 101 will induce an angular acceleration about the z-axis of the club head 113 (since the point of impact occurs some Δy distance away from the cg_y). From the x-axis linear acceleration motion parameters, the data acquisition system 211 of the command station 209 can be capable of determining the force at which the club head 313 impacts a golf ball because the mass of the club head 313 and golf club 10 are known and fixed. Thus, by measuring the above identified linear acceleration and angular acceleration the y-axis location on the club face 301 of the impact can be determined by the data acquisition system 211 of the command station 209. Furthermore, in a similar fashion, by utilizing an additional gyroscope 303 that can measure the angular acceleration about the y-axis of the club head 313, the impact location (of the golf ball) along the club face 301's z-axis can be determined.

In an embodiment, the system could also contain fewer sensors for potentially less cost and potentially less impact on the engineering of the club or additional sensors, or alternative sensors including, but not limited to, additional gyroscopes, additional accelerometers, or devices, such as, but not limited to, force meters, temperature gauges, microcompasses, other sensors or other micromachined devices, such as motors, gears, batteries, or any other type of device that may be desired.

FIG. 4 illustrates an embodiment of a system 30 for analyzing the motion of a sporting equipment, and in particular, as shown in FIG. 4, a golf club 10 having a club head 413, a shaft 407, a handle 409 and a motion sensing system 419. The motion sensing system can include a wide variety of gyroscopes 403 and/or accelerometers 405. FIG. 4 shows an alternative arrangement of the circuitry of a club 10 having a motion sensing system 419 contained within the club head 413. In some embodiments, the golf club 10 of FIG. 4 may designed to appear externally as a standard golf club. In another embodiment,

the golf club 10 can be virtually indistinguishable externally from a standard (i.e., conventional regulation play) golf club which does not contain a motion sensing system. In further embodiments, the motion sensing system may be retrofitted to an existing golf club, by a third party manufacturer. Alternatively, a golf club 10 may be engineered to contain the motion sensing system 419 which may be included as part of the club 10's original manufacturing process. In some embodiments, all components are contained within the golf club 10, while in other embodiments, some or all of the components may be external to the club 10 or may be visible on the club 10.

The system 30 of FIG. 4 further includes a power supply 451, a transmitter 457, a switch 453 and a command station 209. The power supply 451 may be any conventional power supply known in the art. The power supply 451 is preferably a DC source such as a chemical battery which can be placed within the handle 409 of the club 10. The power supply, thus, may be a long life battery that will not need to be replaced over the expected life of the club 10, or, so as to allow battery replacement (or component repair or replacement). In yet another embodiment, the power supply 451 can be a rechargeable battery that may be recharged through any manner known to one of skill in the art. In one embodiment, the recharging can be accomplished through a connector (not shown) connect to the power supply 451. The connector may be an induction plate or cylinder or similar device that can then be connected to a similar connector attached to a charger contained in a golf bag. Such a system could allow a set of golf clubs to be charged while they were not in use but were carried around in the bag.

A switch 453 can be provided in some embodiments so that the system 10 has at least two states: a dormant state, where the measuring of motion parameters is not desired; and an active state, where the measuring of motion parameters is desired. The utilization of active and dormant states can be desirable since much of the motion of the club 10 may be extraneous and not of interest to the golfer, for example, when the golfer is walking to a tee. The active state may be triggered, e.g., by depressing the switch 453, when a player desires to analyze the motion of a golf swing. The switch 453 is not required in all embodiments, however, the use of switch 453 could result in lower energy consumption. Switch 453 can be any type of switch and can be activated by any means known to the art. In one embodiment the switch can be a microswitch built into the handle 409 (as shown) which

may be depressed by the player. Alternatively, the switch 453 could comprises hardware and/or software which operates in conjunction with the data acquisition system 211 and/or the command station 209 to analyze the measured motion parameters so as to detect a "signature" motion that may indicative of a golf swing or an impact with a golf ball. Upon identifying such a signature, the command station 209 may then process a subset of the measured motion parameters established for some period bracketing the signature motion, e.g., for a short period of time before and after contact with the ball. The system 10 may constantly measure the motion parameters and place the measured motion parameters in a memory 455, wherein the measured motion parameters is cycled through the memory 455 (for instance a first-in-first-out (FIFO) memory). Upon detecting the particular motion, i.e., the signature, the command station 209 may then access the measured motion parameters on the memory 455 for a particular period of time, e.g., some period prior to the recorded impact and a period after the recorded impact. In other embodiments, the memory 455 can be utilized independently of the switch 453. For example, the memory 455 could be used to store the measured motion parameters; the command station 209 could then process the measured motion parameters at some later time or date. Furthermore, in some embodiments, the memory 455 may be detachable, e.g., removable and replaceable.

In another embodiment the switch 453 can have more than two modes, for instance the switch 455 could have an off mode indicating the club 10 is in storage, a sleep mode indicating the club 10 is moving but not currently being swung, a practice mode indicating that the golfer is swinging the club 10 but there is no ball to engage, and a play mode where the golfer is swinging the club 10 for the purpose of propelling a ball. Such a multiplicity of modes would enable the golfer to take a few practice swings and make sure they have the desired motion of the club 10 before they actually take the motion and engage the ball with that particular motion. It could also allow for preservation of battery life.

In other embodiments, the switch 453 can consists of sensors and/or micromachines. For example, the switch 453 could contain a pressure transducer sensor capable of detecting some threshold amount of pressure which may be indicative of someone gripping the handle 409 - once the threshold pressure is established, the switch could activate the system 30's active state. Alternatively, the switch 453 could contain an accelerometer sensor capable of detecting some threshold amount of acceleration which may be indicative of a golf swing -

once the threshold acceleration is established, the switch could activate the system 30 s active state. The switch could also be any other type of switch to indicate when the measure motion parameters of the motion sensing system 419 is relevant and should be provided to the command station 209.

The transmitter 457 can be used to transmit the measured motion parameters to a receiver 217 of the command station 219. Since, in one embodiment, circuitry is enclosed within the golf club 10's handle 409 which is limited in space, it may be desirable for the command station to be external to the golf club 10, although in some embodiments, the command station 209 can be coupled to (e.g., attach to or contained within) the golf club 10. In some embodiments, the transmitter 457 can be a wireless communications transmitter capable of transmitting the measured motion parameters to the command station 219 via a wide variety of methods known to the art, including radio frequency (RF), Infrared (IR), microwave, Bluetooth, IEEE 802.11a or any other method or protocol for wireless transmission known now or later discovered. It is not necessary to have a transmitter 457; the measured motion parameters may be extracted from the motion sensing system 419 or memory 455 in any manner known to the art. These include, but not limited to, the club 10 having removable memory 455 and the contents placed on an external system when needed; the club 10 containing a data jack (not shown) or other connector (not shown) which could be hooked directly to an external system allowing download of the contents of the memory; the club 10 connected to the command station 209 via wireline systems as discussed in relation to FIG. 2; or any combination of methods known now or later discussed.

Wireline 475 may be used to connect the components at various locations within the club 10. However, wireline 475 is not necessary and wireless methods or solid state methods could also be used to communicate between the components.

FIG. 5 shows a block diagram of one embodiment of the electronics that could be used in a system such as the one depicted in FIG. 4. Included are a motion sensing system 519 having an accelerometer 505 and gyroscopes 503 and a command station 209. The accelerometer 505 and gyroscopes 503 of the motion sensing system 519 are in channelized communications with the data acquisition system 211 of the command station 209. The

data acquisition system 211 can include a clock 555 for synchronization of the channelized motion parameters measured by the accelerometer 505 and gyroscopes 503. Electrically programmable read-only-memory (EPROM) 561 for storing software algorithms appropriate for the processing of the measured motion parameters may also be present as well as a Random Access Memory 559 for temporarily storing the measured motion parameters and/or the produced data.

The command station 209 may also include a display monitor 215 or similar device that can be used to interpret and display the data acquisition system 211 produced data. In an embodiment, the display monitor 215 can comprises software and/or hardware for use with a portable computing device such as a personal digital assistant (PDA), a laptop computer, or a portable telephone. In another embodiment the display monitor 215 could be a fixed device such as a desktop computer or a computer permanently mounted at a golf course, for instance in a kiosk or in the golf cart.

The display monitor 215 of the command station 209 may be generally designed to display the produced data of the data acquisition system 211 in a format that may be useful for a player or other person interested in the golf swing. FIG. 6 provides one embodiment of such a display. FIG. 6 shows a display 601 from a display monitor 215 utilizing a version of the Windows™ operating system. The display 601 displays produced data in textual and graphical formats. In particular there is a club head position section 641 which can provide a numerical head position 611 indicating the point on the club face where the ball was struck. The impact location data is also shown graphically in graphical display 621. From examining the graphical display 621, for example, one can visually see that the golfer struck the ball slightly too close to the toe of the club (i.e., display 621 indicates a negative y-axis measurement).

Display 601 also shows Peak information 631 which provides information as to the force that was used to hit the ball. This produced data can be useful in determining how hard the ball should have been hit to make the put or to make the drive.

Also included in display 601 is information related to the angular orientation of the club face (e.g., 101) at the time of impact with the ball. This is shown graphically by the rotation diagram 613 and numerically by the values included at calculations 623. In this example, the club face impacted the ball at about 4 degrees difference from where the club

was lined up prior to the start of the stroke. This may have caused an undesired motion to be imparted on the ball.

The display 601 further includes a readout 605 showing the measured motion parameters of the accelerometers and gyroscope for a period of time around the club's impact with the ball. It can be seen in readout 605 that the club had some slight tremors in its path which could lead to the slight mis-impact shown by the other figures. There is also a legend 615 to aid in the interpretation of the readout 605.

Also included in display 601 are buttons 607 which can enable the user to set start and stop times for the measurement of the motion by the club (e.g. to turn off a sleep mode). There is also a button to exit the program when the game or session is complete. Also, there are fill-in areas 609 which can enable the user to store data based on a particular game for later reference, or with which to retrieve data from memory if the player, or another party, would like to examine the particular swings at a later time using the command station 209. Finally, there is shown a control statistics section 610 where various motion parameters regarding the operation of the sensors are displayed. Such a section could be useful for diagnostics on the sensors, or for setting the sensors to insure they read accurately for the play of a particular golfer.

The display 601 of FIG. 6 is merely one example of the types of information that could be presented. In one embodiment, the command station 209 can allow a golfer to examine the produced data, replay or simulate a portion of the movement (e.g., golf swing), to compare the movement to another movement, or to even predict the result of the motion (for instance the distance and direction that the ball is expected to travel). This can also be combined with information from sensors external to the motion sensing system, for instance weather sensors, GPS systems, or terrain maps to determine additional factors related to the shot, or to do anything else that could be useful to the golfer to determine how the particular motion they made may have effected the resulting performance. Further, although FIG. 6 illustrates a visual display, audio or other sensory output could be provided instead of, or in addition to, visual output. The output could also be used to provide feedback to the user during the swing, for instance if the user had a habit of twisting the club face during the swing, the club handle could tingle indicating that the club face is being twisted and

encouraging the player to try and eliminate the behavior before actually following through with the putt.

In another embodiment, the golfer's performance could be compared against the performance of a professional or highly skilled golfer performing a similar putt (or drive off a tee shot) to show the differences in performance. The display 601 could also include information showing the layout of the course or green, and a map showing a mathematical calculation of the putt (or drive) as made compared to a putt (or drive) which would have gone in the cup (or was made by another golfer). In yet another embodiment, the display 601 could provide a golfer with their performance over time. For instance their performance over nine holes could be shown simultaneously to attempt to point out recursive problems. The display 601 could also provide suggestions about what might be causing the problems and how the golfer may be able to improve their game.

Although the system described in FIGS 1-6 describes the motion sensing system as being located in the head of the golf club and the other components located in various other parts of the club, it will be readily understood by one of skill in the art that the sensors and components could be placed anywhere within the club where the motion of that portion of the club is desired or space allows. The motion of the club head is generally measured because the club head actually impacts the golf ball and therefore provides the motion to the ball, whose resultant location is what is desired. Alternatively or additionally, sensors could be placed in the shaft or handle of the golf club to enable a recordation of the motion of those items so as to use their motion in comparing golf swings. Such a measurement may be desirable to determine the result on the swing of the flexibility of the club, for example.

The data provided from the motion sensing system could be used as part of a training program in another embodiment of the invention. In one such embodiment, a particularly fine athlete could be provided with devices like those above and could participate in one or more sporting events while all their motion was recorded. Their success could then be analyzed and used to train other athletes to perform in a similar manner. This could be performed by providing the training athlete with a similar analysis of motion, comparing the differences between the motions, and developing a training routine, training materials, or specially designed sporting goods to help the training athlete to better conform their movement to the successful athlete's movement. Since the motion

of the club head is recorded, the training regime could encourage the player to copy the club's motion, instead of the skilled player's motion. This would then enable the player to adapt a comfortable play style which emulates the skilled player's results, but may be a completely different, and personalized, style.

The produced data could also be used in the design of sporting equipment. For instance, a designer could build a range of sporting goods incorporating different principles and provide these to an athlete. They can then compare success and failure of the designs of the sporting goods, along with the motion of the sporting goods to develop new sporting goods that promote the ability of, at least some, athletes to perform better. Sporting goods could also be manufactured with a higher degree of customization for the athlete by analyzing the motion of an athlete with a particular sporting good or goods and then selecting or designing a sporting good that capitalizes on the unique abilities of that athlete.

In a still further embodiment, the produced data could be used to provide better simulations and predictions of motion. A putting simulator could be provided which enables a golfer to swing a club at a tethered ball that, based on the motion of the club allows for a more realistic practice experience in a limited environment. For instance, it would be possible to provide for a simulated green (for instance via a video screen) with a club including a motion sensing system and a tethered ball. A computer could then analyze the hit at the moment of impact, compute the course of the ball and show the ball move on the screen with a high degree of accuracy.

Such systems could also predict the outcome of a particular sporting action in real time. This could enable a commentator and/or player to know at the instant a ball was hit that it was going in the cup. This commentator ability could also allow a golfer's motion can be analyzed as they are playing allowing a spectator to know that one particular golfer is hitting their putts or drives much cleaner or better than another golfer, or compared to the way they usually play. The information could also be used by coaches or trainers during a sporting event to determine if a player is not performing in a normal manner and allow the coach to determine if the player may be having an off day, and why the player may be having an off day. The information could also be provided via television, Internet or other networks to the public, spectators, or other interested parties.

The devices can also be used in sports safety and in sports medicine. Since the motion of an athlete may always be recorded, if the athlete was to suffer an injury, for instance a back injury during a golf swing, medical professionals could review the recorded motion to determine the nature of the athletes injury from the difference in the motion and what that could mean for underlying body structure and what was injured. The system could also be used to detect an athlete who may be injured but is playing on by detecting subtle changes in the motion of their play. Such a system could allow a coach or trainer to make a decision that the athlete should discontinue play to avoid further injury, even if the athlete thinks he is still fit to continue.

The systems and methods could also be used medically to rehabilitate from injuries or surgery. With a recording of the golfer's original motion the golfer can train after an injury to duplicate that motion as their body heals, this could lead to faster recovery of athletic ability and performance after injury or surgery, even if the athleteis required to live is a restricted environment (such as a hospital). Such a system could alsobe used if the player takes a leave of absence from the sport for a period of time. It could also be used if the player wished to alter a specific facet of their play at a future time, forinstance because of a switch in sporting equipment manufacturers.

In yet a further embodiment, the recorded motion could be used to build a machine to accurately simulate the motion that has been recorded. In this way, robots or other machines could be built which were particularly good at putting exactly like a particular player. The machine could then be provided with clubs manufactured to deal with the particular problem and designed to correct the problem so the machine can test them. Therefore the system could result in a player being provided with custom designed clubs that will help them correct a problem with their game, or may even correct it for them, that have been engineered based on exactly how they swing.

The motion could also be used to create particularly good visual representations of the motion allowing creators in the visual arts, for instanse special effects producers in the movies, to simulate the golfing motion in an animated figure.

While the invention has been disclosed in connection with the preferred embodiments shown and described in detail, various modifications and improvements thereon will become readily apparent to those skilled in the art. Accordingly, the spirit and scope of the present invention is to be determined by the following claims.

What is claimed is:

1. A system for measuring motion of a sporting equipment, the system comprising: a motion sensing system in communications with said sporting equipment to measure motion parameters, wherein said motion sensing system comprises at least one of: at least one accelerometer and at least one gyroscope.

2. The system of claim 1, further comprising: a command station comprising a data acquisition system to process said measured motion parameters and produce data.

3. The system of claim 1, wherein said sporting equipment is at least one of the following: a golf club, a baseball bat, a hockey stick, a football and a tennis racquet.

4. The system of claim 1, wherein said motion sensing system is located on said sporting equipment.

5. The system of claim 1, wherein said motion sensing system is located within said sporting equipment.

6. The system of claim 1, wherein said at least one accelerometer is a micromachine device.

7. The system of claim 1, wherein said at least one gyroscope is a micromachine device.

8. The system of claim 1, wherein said motion sensing system comprises at least one accelerometer and at least one gyroscope.

9. The system of claim 1, wherein said motion sensing system includes an accelerometer, a first gyroscope for detecting an angular acceleration relative to a first axis and a second gyroscope for detecting an angular acceleration relative to a second axis.

10. The system of claim 9, wherein said second axis is orthogonal to said first axis.

11. The system of claim 1, wherein said motion sensing system includes:
a first gyroscope for detecting angular acceleration relative to a first axis;
a first accelerometer for detecting linear acceleration relative to a first axis;
a second gyroscope for detecting angular acceleration relative to a second axis;
a second accelerometer for detecting linear acceleration relative to a second axis;
a third gyroscope for detecting angular acceleration relative to a third axis; and
a third accelerometer for detecting linear acceleration relative to a second axis, and wherein said second axis is orthogonal to said first axis and said third axis is orthogonal to said first and said second axes.

12. The system of claim 2, wherein said data acquisition system processes said measured motion parameters and produces data representative of an impact location of said sporting equipment.

13. The system of claim 2, wherein said data acquisition system processes said measured motion parameters and produces data representative of a velocity of said sporting equipment.

14. The system of claim 2, wherein said data acquisition system processes said measured motion parameters to produce data representative of an angular orientation of said sporting equipment.

15. The system of claim 1, wherein said motion sensing system comprises memory for storing said measured motion parameters.

16. The system of claim 15, wherein said memory is detachable from said sporting equipment.

17. The system of claim 1, further comprising:
a transmitter to transmit said measured motion parameters to a command station.

18. The system of claim 17, wherein said transmitter is a wireless communications transmitter.

19. The system of claim 18, wherein said wireless communications transmitter transmits said measured motion parameters in accordance with one of the following wireless communication protocols: Bluetooth and IEEE 804.12.

20. The system of claim 18, wherein said wireless communications transmitter is a radio-frequency transmitter.

21. The system of claim 18, wherein said wireless communications transmitter is an Infrared-frequency transmitter.

22. The system of claim 2, wherein the data acquisition system includes a data error correction module for compensating for an error rate of said motion sensing system.

23. The system of claim 1, further comprising a command station that includes a display monitor.

24. The system of claim 2, wherein said data acquisition system compares said produced data to previously stored data.

25. A system for analyzing a golf swing, comprising:
a golf club head; and
a motion sensing system in communications with said golf club head to measure golf swing motion parameters, wherein said motion sensing system comprises at least one of: at least one accelerometer and at least one gyroscope.

26. The system of claim 25, further comprising:

a command station comprising a data acquisition system to process said measured motion parameters and produce data.

27. The system of claim 25, wherein said motion sensing system is located on said golf club head.

28. The system of claim 25, wherein said motion sensing system is located within said golf club head.

29. The system of claim 25, wherein said motion sensing system comprises at least one accelerometer and at least one gyroscope.

30. The system of claim 25, wherein said motion sensing system includes an accelerometer, a first gyroscope for detecting an angular acceleration relative to a first axis and a second gyroscope for detecting an angular acceleration relative to a second axis

31. The system of claim 30, wherein said second axis is orthogonal to said first axis.

32. The system of claim 25, wherein said motion sensing system includes:

a first gyroscope for detecting angular acceleration relative to a first axis;

a first accelerometer for detecting linear acceleration relative to a first axis;

a second gyroscope for detecting angular acceleration relative to a second axis;

a second accelerometer for detecting linear acceleration relative to a second axis;

a third gyroscope for detecting angular acceleration relative to a third axis; and

a third accelerometer for detecting linear acceleration relative to a second axis, and wherein said second axis is orthogonal to said first axis and said third axis is orthogonal to said first and said second axes.

42. The system of claim 41, wherein said wireless communications transmitter transmits said measured parameter data in accordance with one of the following wireless communication protocols: Bluetooth and IEEE 804.12.

43. The system of claim 41, wherein said wireless communications transmitter is a radio-frequency transmitter.

44. The system of claim 41, wherein said wireless communications transmitter is an Infrared-frequency transmitter.

45. The system of claim 26, wherein the data acquisition system includes a data error correction module for compensating for an error rate of said motion sensing system.

46. The system of claim 25, further comprising a command station that includes a display monitor.

47. The system of claim 26, wherein said data acquisition system compares said produced data to previously stored data.

48. The system of claim 25, wherein said golf club head is a putter.

49. The system of claim 25, wherein said golf club head is a driver.

50. A golf club, comprising:

a club head;

a shaft; and

a motion sensing system to measure motion parameters of said golf club during a golf swing, wherein said motion sensing system comprises at least one of: at least one accelerometer and at least one gyroscope.

33. The system of claim 26, wherein said data acquisition system processes said measured motion parameters and produces data representative of an impact location of a golf ball on a club face of said club head.

34. The system of claim 26, wherein said data acquisition system processes said measured motion parameters and produces data representative of a velocity of said club head.

35. The system of claim 26, wherein said data acquisition system processes said measured motion parameters and produces data representative of an angular orientation of a club face of said club head.

36. The system of claim 35, wherein said data acquisition system provides an angular orientation of said club face when said club face impacts a golf ball.

37. The system of claim 36, wherein said data acquisition system provides a reference angular orientation of said club face at an initiation of said golf swing.

38. The system of claim 25, wherein said motion sensing system comprising memory for storing said measured motion parameters.

39. The system of claim 38, wherein said memory is detachable from said golf club.

40. The system of claim 25, further comprising:

a transmitter to transmit said measured motion parameters to a command station.

41. The system of claim 40, wherein said transmitter is a wireless communications transmitter.

51. The golf club of claim 50, wherein said motion sensing system is located on said club head.

52. The golf club of claim 50, wherein said motion sensing system is located within said club head.

53. The golf club of claim 50, wherein said motion sensing system is located on said shaft.

54. The golf club of claim 50, wherein said motion sensing system is located within said shaft.

55. The golf club of claim 50, wherein said motion sensing system comprises at least one accelerometer and at least one gyroscope.

56. The golf club of claim 50, wherein said motion sensing system includes an accelerometer, a first gyroscope for detecting an angular acceleration relative to a first axis, and a second gyroscope for detecting an angular acceleration relative to a second axis.

57. The golf club of claim 56, wherein said second axis is orthogonal to said first axis.

58. The golf club of claim 50, wherein said motion sensing system includes:
a first gyroscope for detecting angular acceleration relative to a first axis;
a first accelerometer for detecting linear acceleration relative to a first axis;
a second gyroscope for detecting angular acceleration relative to a second axis;
a second accelerometer for detecting linear acceleration relative to a second axis;
a third gyroscope for detecting angular acceleration relative to a third axis; and
a third accelerometer for detecting linear acceleration relative to a second axis, and wherein said second axis is orthogonal to said first axis and said third axis is orthogonal to said first and said second axes.

59. The golf club of claim 50, further comprising memory for storing said measured motion parameters.

60. The golf club of claim 59, wherein said memory is detachable from said golf club.

61. The golf club of claim 50, further comprising a transmitter to transmitting said measured motion parameters to a command station.

62. The golf club of claim 61, wherein said transmitter is a wireless communications transmitter.

63. The golf club of claim 62, wherein said wireless communications transmitter transmits said measured parameter data in accordance with one of the following wireless communication protocols: Bluetooth and IEEE 804.12.

64. The golf club of claim 62, wherein said wireless communications transmitter is a radio-frequency transmitter.

65. The golf club of claim 62, wherein said wireless communications transmitter is an Infrared-frequency transmitter.

66. The golf club of claim 50, wherein said motion sensing system is removable and replaceable from said golf club.

67. The golf club of claim 50, wherein said golf club is a putter.

68. The golf club of claim 50, wherein said golf club is a driver.

69. A method for analyzing a golf swing, comprising:

having a motion sensing system in communications with a golf club to measure golf swing motion parameters, wherein said motion sensing system comprises at least one of: at least one accelerometer and at least one gyroscope; and

processing said measured motion parameters to produce data.

70. The method of claim 69, further comprising:
locating said motion sensing system on a club head of said golf club.

71. The method of claim 69, further comprising:
locating said motion sensing system within a club head of said golf club.

72. The method of claim 69, wherein said motion sensing system comprises at least one accelerometer and at least one gyroscope.

73. The method of claim 69, wherein said motion sensing system includes an accelerometer, a first gyroscope for detecting an angular acceleration relative to a first axis and a second gyroscope for detecting an angular acceleration relative to a second axis, and wherein said second axis is orthogonal to said first axis.

74. The method of claim 69, wherein said motion sensing system includes:
a first gyroscope for detecting angular acceleration relative to a first axis;
a first accelerometer for detecting linear acceleration relative to a first axis;
a second gyroscope for detecting angular acceleration relative to a second axis;
a second accelerometer for detecting linear acceleration relative to a second axis;
a third gyroscope for detecting angular acceleration relative to a third axis; and
a third accelerometer for detecting linear acceleration relative to a second axis, and wherein said second axis is orthogonal to said first axis and said third axis is orthogonal to said first and said second axes.

75. The method of claim 69, wherein said data is representative of an impact location of a golf ball on a club face of said golf club.

76. The method of claim 69, wherein said data is representative of a velocity of a club head of said golf club.

77. The method of claim 69, wherein said data is representative of an angular orientation of a club face of said golf club.

78. The method of claim 69, further comprising:
storing said measured motion parameters.

79. The method of claim 69, further comprising:
transmitting said measured motion parameters to said command station.

80. The method of claim 69, wherein said processing of said measured motion parameters includes compensating for an error rate of said motion sensing system.

81. The method of claim 69, further comprising:
displaying said data on a display monitor.

82. The method of claim 69, further comprising:
comparing said produced data to previously stored data.

1/6

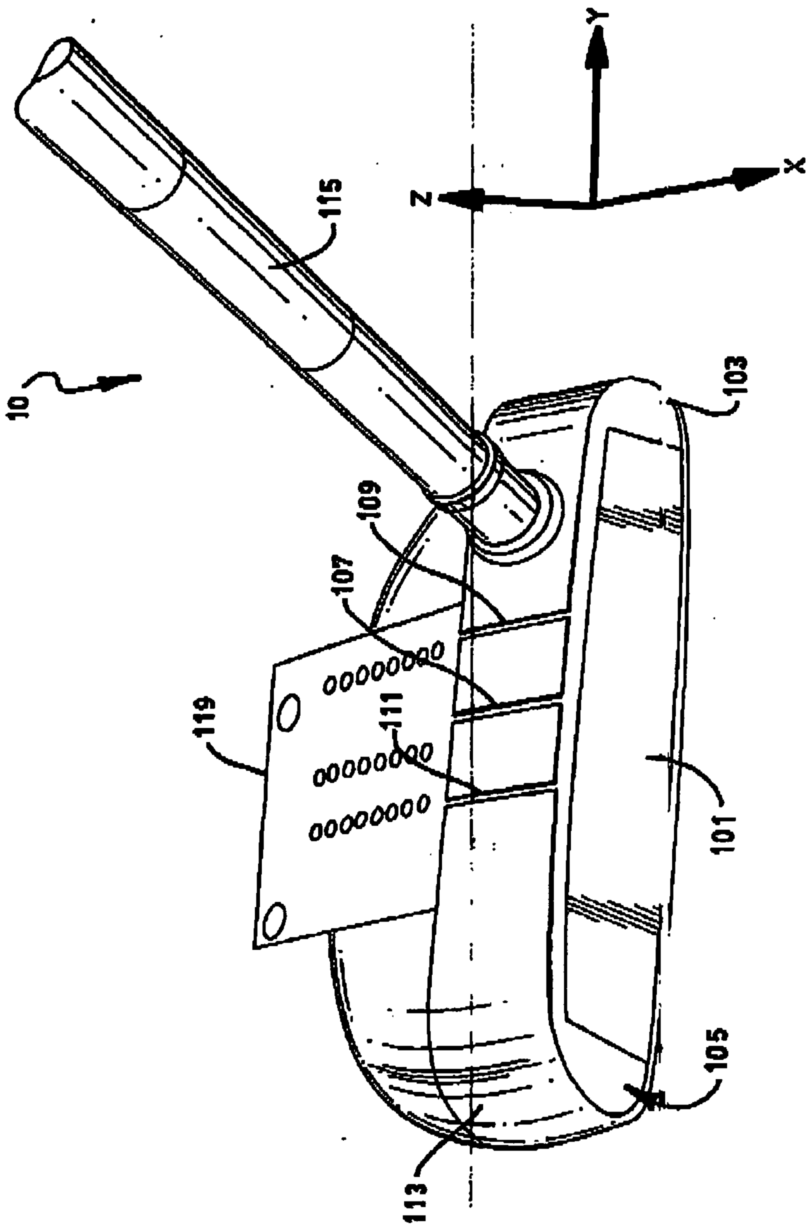

Y
X
Z
115
10
103
109
107
00000000
119
111
00000000
00000000
101
105
113

FIG. 1

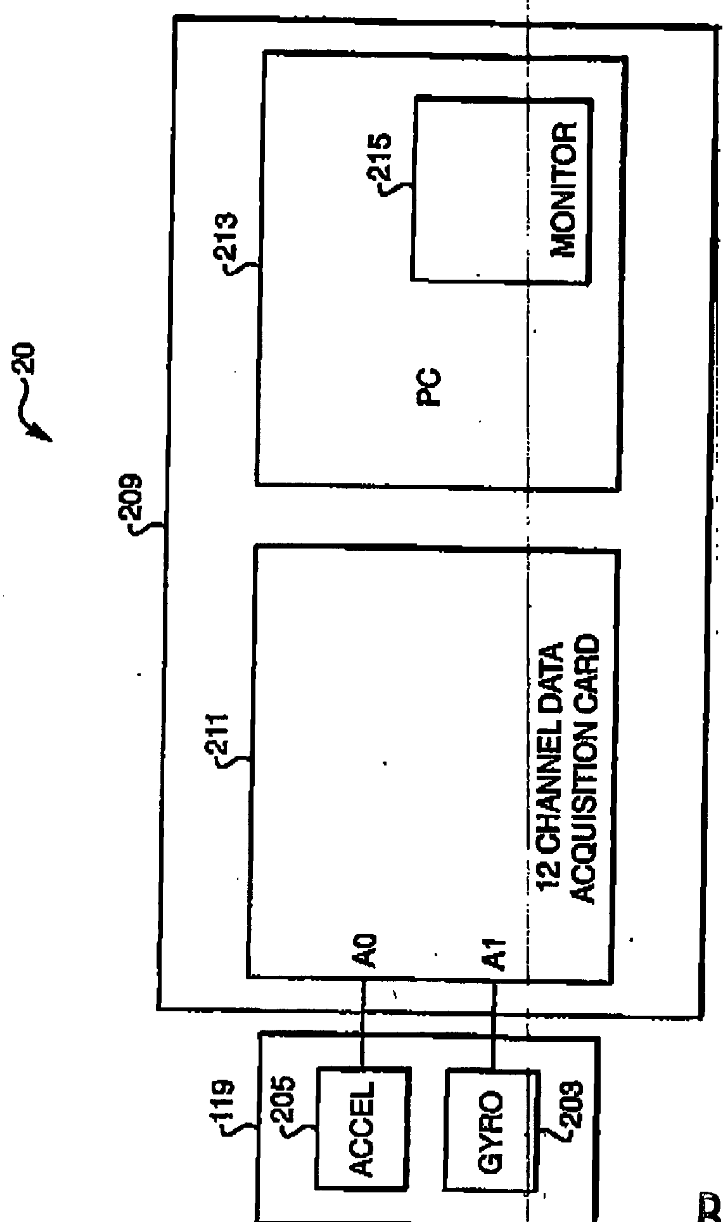

20
209
213
215
MONITOR
PC
211
12 CHANNEL DATA ACQUISITION CARD
A0
A1
119
205
ACCEL
GYRO
203

FIG. 2

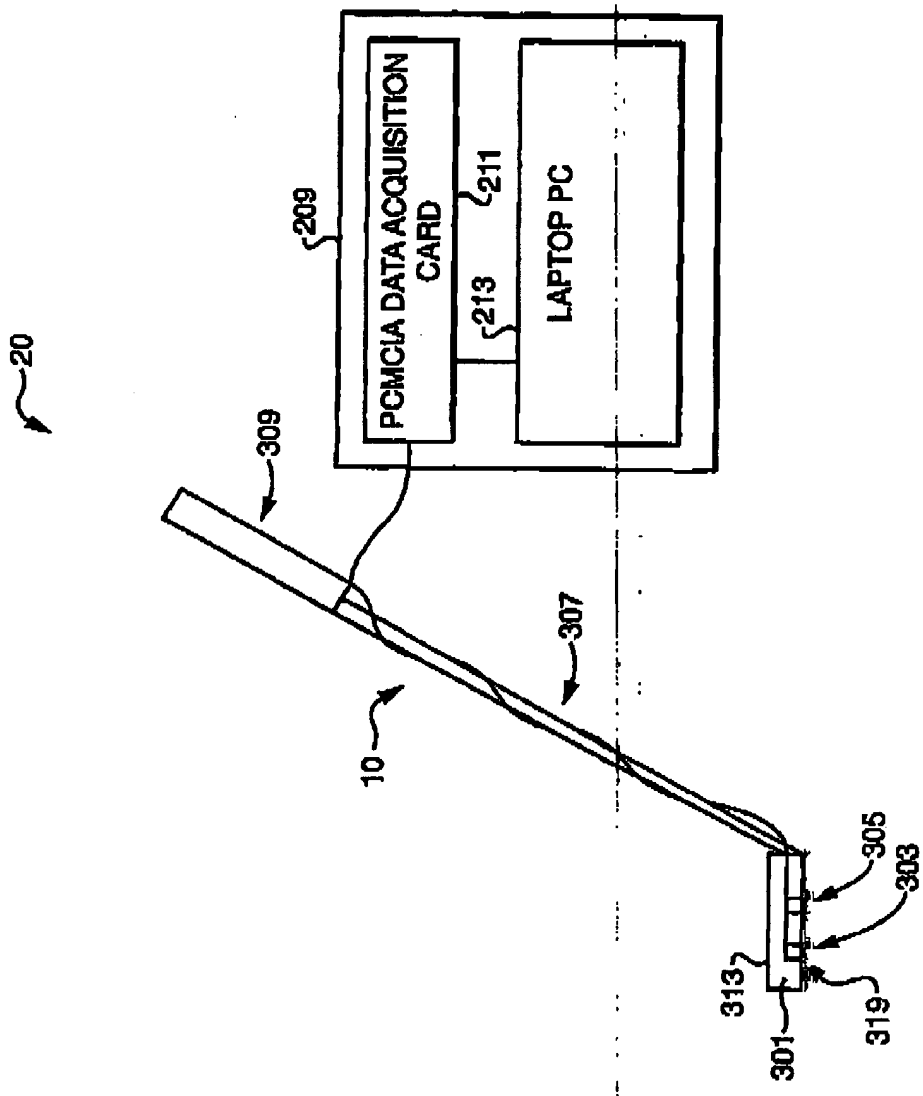

20
209
PCMCIA DATA ACQUISITION CARD
211
213
LAPTOP PC
309
307
10
305
303
313
301
319

FIG. 3

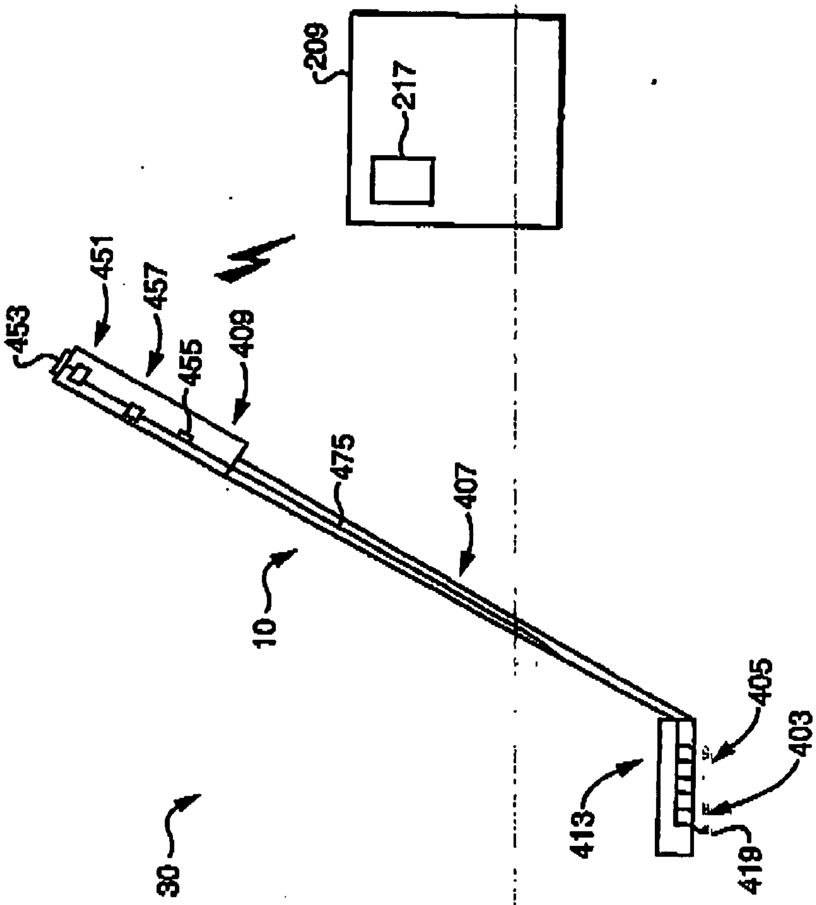
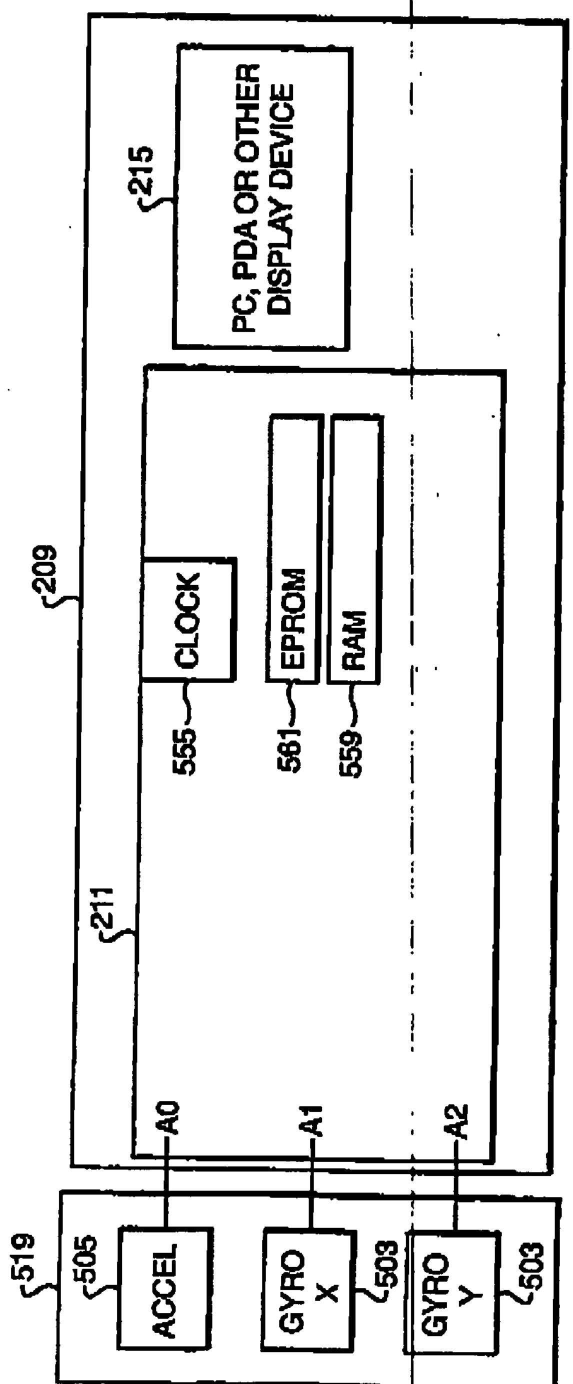


FIG. 4



PC, PDA OR OTHER DISPLAY DEVICE
215
209
211
CLOCK
555
EPROM
561
RAM
559
A0
A1
A2
519
505
ACCEL
GYRO X
503
GYRO Y
503

FIG. 5

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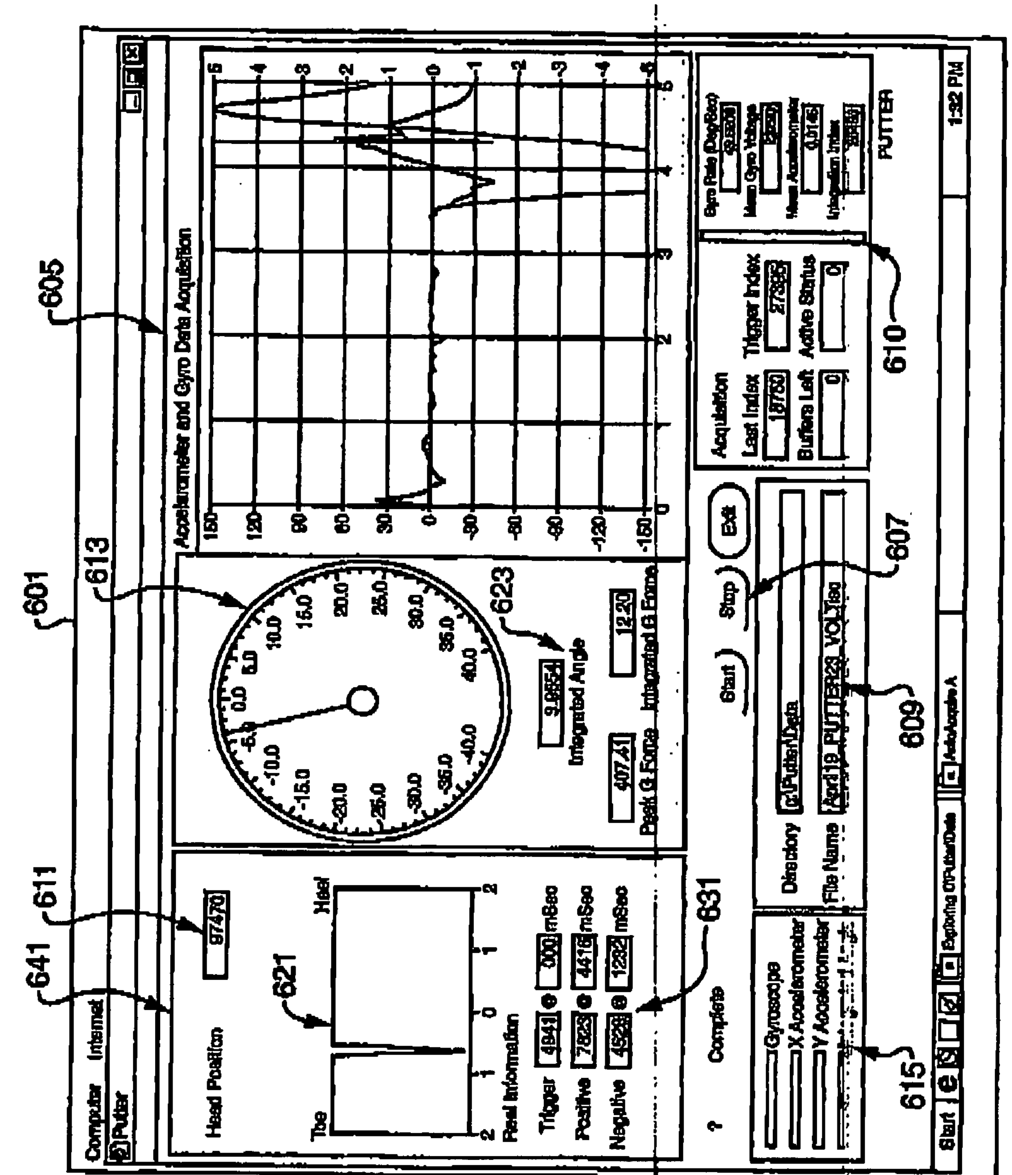

FIG. 6

BEST AVAILABLE CO